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CHANGES IN DISCHARGE REGIMES OF RIVERS IN CROATIA

Ivan Čanjevac, Danijel Orešić

The Krka River upstream from Skradin Falls, Croatia.

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Changes in discharge regimes of rivers in Croatia

ABSTRACT: This paper presents the results of the first comprehensive national analysis of changes in discharge regimes of rivers in Croatia. Seven types of discharge regimes have been defined for rivers in Croatia. We analyzed the changes in discharge regimes of all types, comparing the standard period from 1961 to 1990 with the most recent period from 1990 to 2009. We found evidence of a redistribution of discharge throughout the year, an increase in autumn and winter discharges (especially for rivers dominantly fed by snowmelt), and a decrease in summer discharge values. Furthermore, we detected a change in the month of the appearance of mean discharge maxima and minima. In most cases, the changes can be explained by changes in the regime of climate elements (temperature, precipitation, and evapotranspiration). The results are consistent with those from upstream countries; that is, Slovenia, Austria, and Bosnia and Herzegovina.

KEYWORDS: geography, hydrology, discharge, river regime, module coefficients, Croatia

Spremembe v pretočnem režimu hrvaških rek

POVZETEK: V članku so predstavljeni izsledki prve pregledne nacionalne analize sprememb v pretočnem režimu rek na Hrvaškem. V analizi je bilo ugotovljenih sedem različnih vrst pretočnih režimov. Avtorja sta pri vsaki preučevala spremembe, pri čemer sta primerjala obdobji med letoma 1961 in 1990 ter 1990 in 2009. Ugotovitve so pokazale spremembe v porazdelitvi pretoka čez leto, povečanje jesenskega in zimskega pretoka (zlasti pri rekah, na pretok katerih večinoma vpliva taljenje snega) ter zmanjšanje pretoka v poletnih mesecih. Poleg tega se je spremenil tudi mesec najnižjega in najvišjega povprečnega rečnega pretoka. V večini primerov lahko spremembe pojasnimo s spremembami podnebnih dejavnikov (temperature, padavin in evapotranspiracije). Izsledki se ujemajo z rezultati analiz, opravljenih v državah gorvodno (tj. Sloveniji, Avstriji ter Bosni in Hercegovini).

KLJUČNE BESEDE: geografija, hidrologija, pretok, rečni režim, koeficienti modulov, Hrvaška

Ivan Čanjevac, Danijel Orešić
University of Zagreb, Faculty of Science, Department of Geography
canjevac@geog.pmf.hr, doresic@geog.pmf.hr

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1 Introduction

The aim of this study was to assess recent changes in discharge regimes in Croatia. What is the effect of (evident) climate change or oscillation on water resources in Croatia? Are there any significant changes in the discharge regimes of rivers in Croatia? Is it possible to draw any general conclusions regarding the change in discharge regimes that could confirm climate change observations?

Discharge regimes have traditionally been a major hydrogeographical research topic (Pardé 1933; Ilešič 1947; Grimm 1968; Riđanović 1993; Hrvatin 1998; Frantar 2003; Frantar and Hrvatin 2005). This is probably because they are the result of complex physical geographical characteristics, as well as the socio-geographical development of the upstream area. Although station-specific discharge regimes are mainly the result of the climate characteristics of the basin area, climate change or oscillations can and usually are reflected in discharge regimes. This study is the first comprehensive nationwide assessment of changes in discharge regimes.

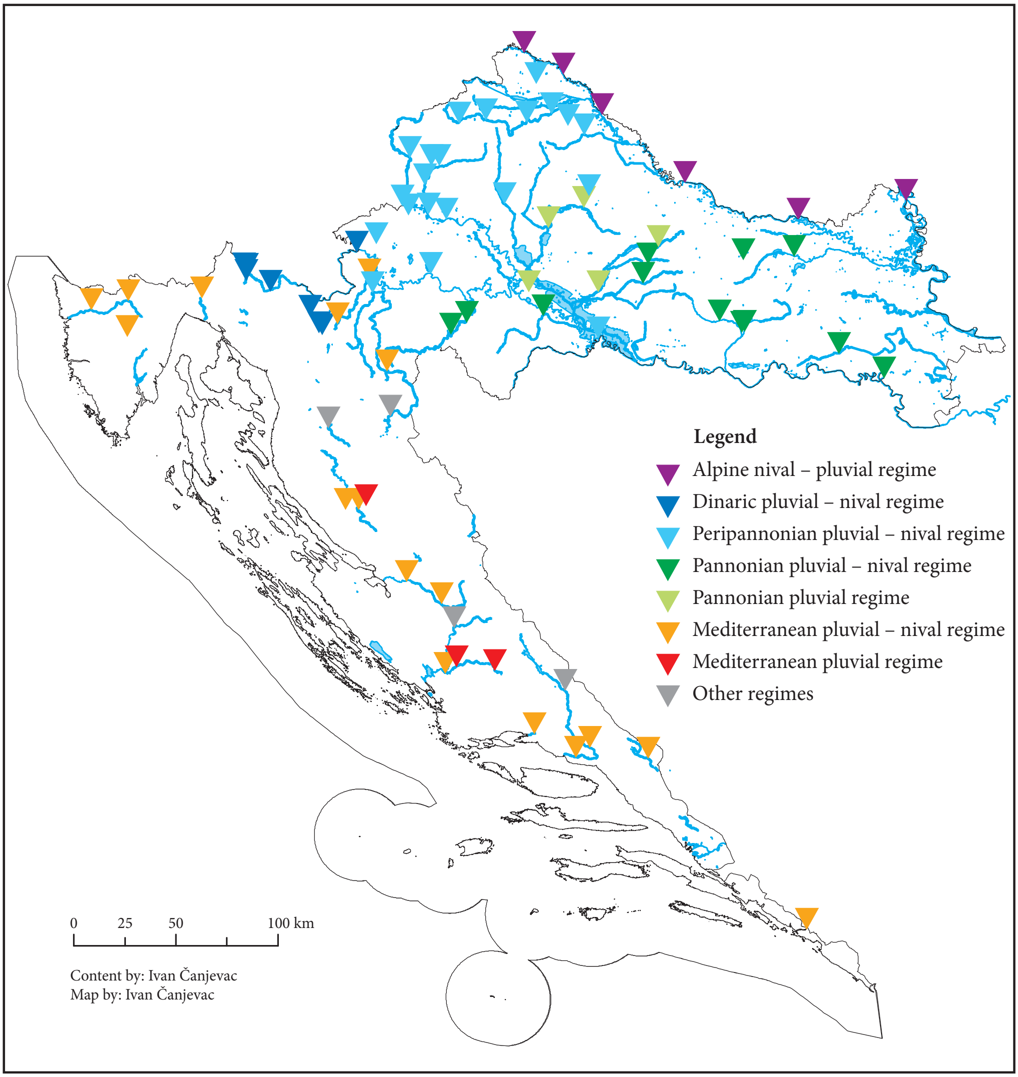

Figure 1: Types of discharge regimes in Croatia (Čanjevac 2013).

The study covers rivers and stations in Croatia with available data. Croatia has heterogeneous physical-geographical characteristics. It lies at the intersection of the Pannonian Plain, the Dinaric Alps, and the Adriatic Sea, covering an area of 56,594 km^2 with around 4.3 million inhabitants (Croatian … 2014). Its diverse climate, geological, and geomorphological conditions result in a variety of discharge regimes of rivers (Čanjevac 2013). For the purpose of this study, we compare the standard period (1961–1990) with the most recent twenty-year period (1990–2009). We are aware of possible different conclusions due to different lengths of time series, but we consider a twenty-year period long enough to avoid interannual oscillations (Dukić 1984; Shaw et al. 2010).

The discharge regimes of rivers in Croatia were studied by Ilešič (1947) and Riđanović (1993), who covered only large rivers. Regional analysis of discharge and river regimes was carried out for rivers in the Lika region (Pejnović 1991), the catchment of the Krapina River (Orešić 1995), and the catchments of the Rječina and Mirna Rivers (Knežević 2001, 2004). In addition, the discharge regimes of some rivers in Croatia were analyzed within larger-scale studies (Belz et al. 2004; Kovacs 2010). All of these studies cover parts of Croatia and did not seek to obtain the wider picture necessary to understand processes and changes for the entire Croatian area and for the correlation with neighboring and upstream countries. Therefore, for methodological reasons and spatial correlation, we also analyze the research findings from nearby countries; namely, Slovenia (Hrvatin 1998; Ulaga 2002; Frantar 2003, 2005, 2007; Frantar and Hrvatin 2005; Brilly et al. 2007; Ulaga et al. 2008), Austria (Fürst et al. 2008, 2010), Germany (Bormann 2010), Hungary (Belz et al. 2004), and Bosnia and Herzegovina (Hidrološka studija površinskih voda BiH 2012). Those studies analyze recent changes in river discharge and discharge regimes in their respective countries and for rivers in the wider area of the Danube Basin. Due to changes observed for rivers linked to changes in snowfall and snow cover duration, Swiss research is also analyzed (Birsan et al. 2005).

2 Methods

This study uses the mean monthly discharge data from 116 hydrological stations in Croatia (Meteorological … 2014). The main selection criterion was the length of time series without gaps. We chose seventy-six stations on fifty-one rivers for our analysis of the discharge regime change. All of the data were obtained from the Meteorological and Hydrological Service of Croatia.

According to the recent typology of discharge regimes (for the period 1990–2009), there are seven types of discharge regimes in Croatia (Čanjevac 2013).

The changes in each of the types were analyzed. A comparison and analysis of discharge regimes for two periods (1961–1990 and 1990–2009) were made comparing the values of module coefficients. This paper presents changes of discharge regimes in the characteristic (typical) stations for each type.

3 Results

3.1 Alpine nival-pluvial regime

Rivers with an Alpine nival-pluvial regime in Croatia are the Drava, the Mura, and the Danube. The regimes of these rivers and the uniformity of discharge in particular are affected by the construction of dams for large hydropower plants. The mechanisms of water input and change in characteristics of this regime type are shown based on the example of the Terezino Polje station on the Drava River. The regimes of the 1961–1990 standard period were compared to the period (1990-2000) for which the recent typology (Čanjevac 2013) was made (Figure 2).

There is evidence of changes and a transition from a nival (nival-glacial; Riđanović 1993) regime in the 1961–1990 period towards a nival-pluvial regime in the last period. This can be concluded from the decreased values of module coefficients in the high-water period, when the main input comes from snow and glacier melt, and increased coefficient values in the low-water period from September to January. Between the two periods studied, the mean monthly discharge value at the annual level decreased by 10%, from 533.37 to 480.02 m^3/s. Indirectly, we conclude that feeding by snowmelt is lessening (there is a decrease in the retardation effect) and feeding by rainfall is increasing, which corresponds to processes of climate element change in the basins analyzed (Gajić-Čapka and Cesarec 2010).

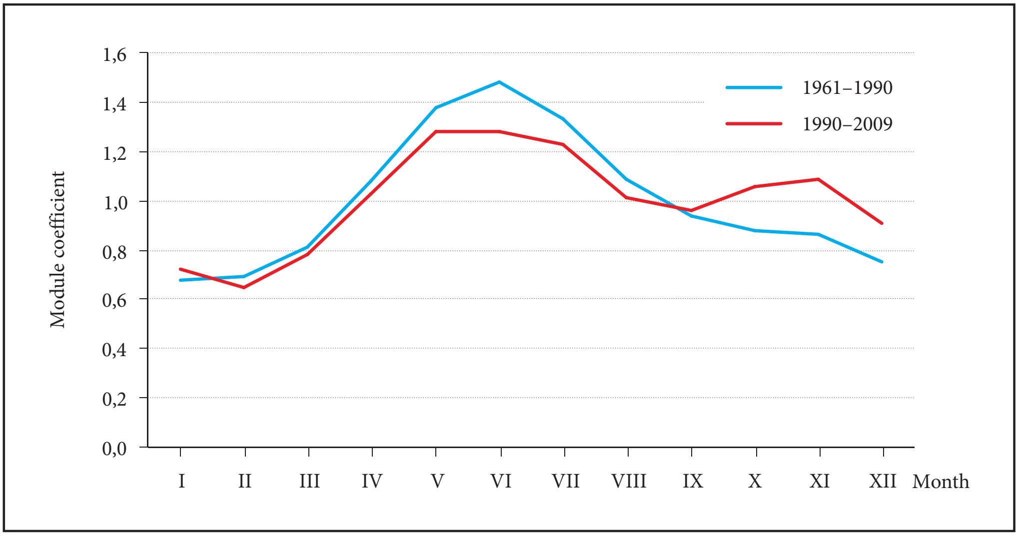

Figure 2: Module coefficient values of the Drava at the Terezino Polje station; an Alpine nival-pluvial regime.

3.2 Dinaric pluvial-nival regime

The Kupa, Čabranka, Kupica, Gornja Dobra, and Vitunjčica rivers are characterized by a Dinaric pluvial-nival regime. In order to illustrate the changes in this regime type, we chose the Kupa River and the Hrvatsko station (Figure 3). There is a notable decrease in mean monthly discharge values for the Kupa at that station by about 8% from 20.65 m^3/s to 18.94 m^3/s.

Through a parallel analysis of the regimes in the two periods, an increase in module coefficients was recorded from September to February in the second period, with the most marked increase in October.

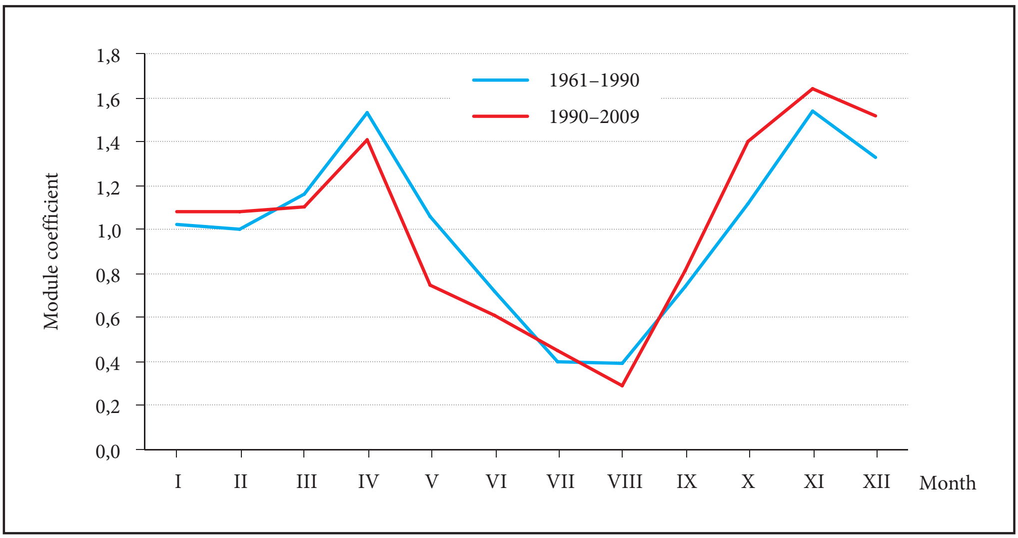

Figure 3: Module coefficient values of the Kupa River at the Hrvatsko station; a Dinaric pluvial-nival regime.

On the other hand, there was a fall in the values of module coefficients from March to August, with the most marked one occurring in May. It is precisely this pronounced decrease in discharge in May that indicates a decrease in snowmelt proportion in the total input of the river. This is the cause of increased discharges in the winter months, whereas those of the spring months are decreasing due to a smaller amount of snow, which also melts earlier. Another change noticed is that the autumn maximum is more marked than the spring one, whereas they were equal in the standard period. Generally, the autumn months have become wetter and the spring months have become drier. Furthermore, the decrease in discharge in August, which is around one-third of the average annual discharge, is a bit alarming. Due to such changes, in the twenty-year period observed the difference between the months with the highest and lowest discharge has increased significantly.

3.3 Peripannonian pluvial-nival regime

This type of regime includes over 30% of the stations analyzed. Rivers with a Peripannonian pluvial-nival regime are the Bednja, Krapina, Krapinčica, Horvatska, Sutla, Lonja, Bjelovatska, Gliboki, Koprivnica, Sava (stations: Podsused Žičara, Zagreb, Jasenovac), Bregana, Gradna, Trnava, Kupčina, Mrežnica, and Kupa (Jamnička Kiselica station). The three stations included on the Sava show characteristics of its upper and middle course in Croatia. This regime type is the most heterogeneous one and shows the diversity of climate conditions of runoff at both the meso-regional and micro-regional levels.

The Bednja River at the Tuhovec station was chosen to assess the change in this type of regime (Figure 4). The mean monthly discharge of the Bednja at the Tuhovec station between the two periods fell from 6.62 to 4.84 m^3/s (i.e., 27%).

Through a comparative analysis of the regimes, an increase in coefficient values from September to January was observed, along with a decrease from February to August. December showed the most marked increase in module coefficients, whereas the decrease, on the other hand, was most pronounced in March. Such changes indicate dryness in the spring and summer months, probably caused by reduced precipitation, but most of all by the increase in mean monthly temperatures and evapotranspiration values (Pandžić et al. 2009). The results are indicative, but in order to confirm these causal connections any future research will require an analysis of available climate elements' data series.

The Sava regime in Zagreb is somewhat different from other streams and requires a more detailed analysis (Figure 5).

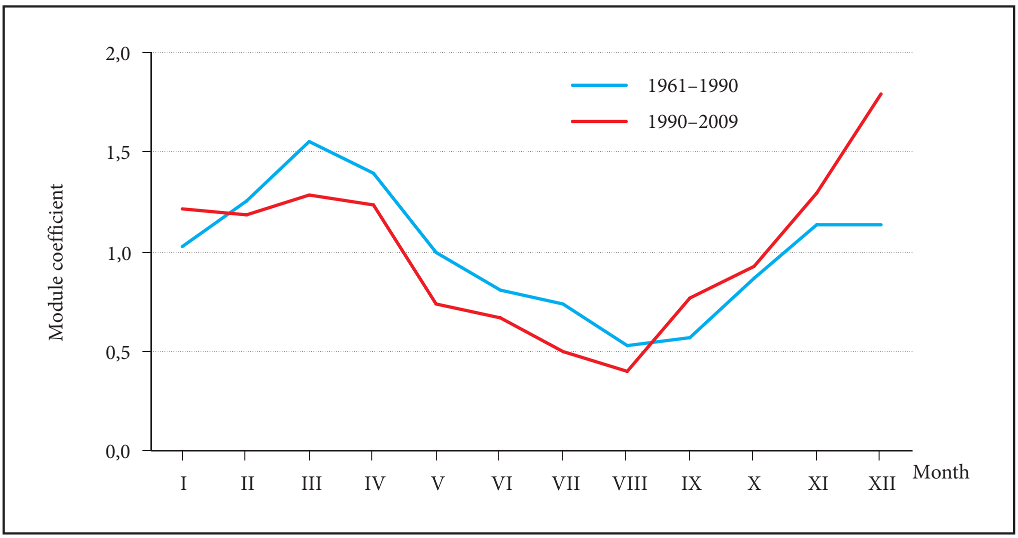

Figure 4: Module coefficient values of the Bednja River at the Tuhovec station; a Peripannonian pluvial-nival regime.

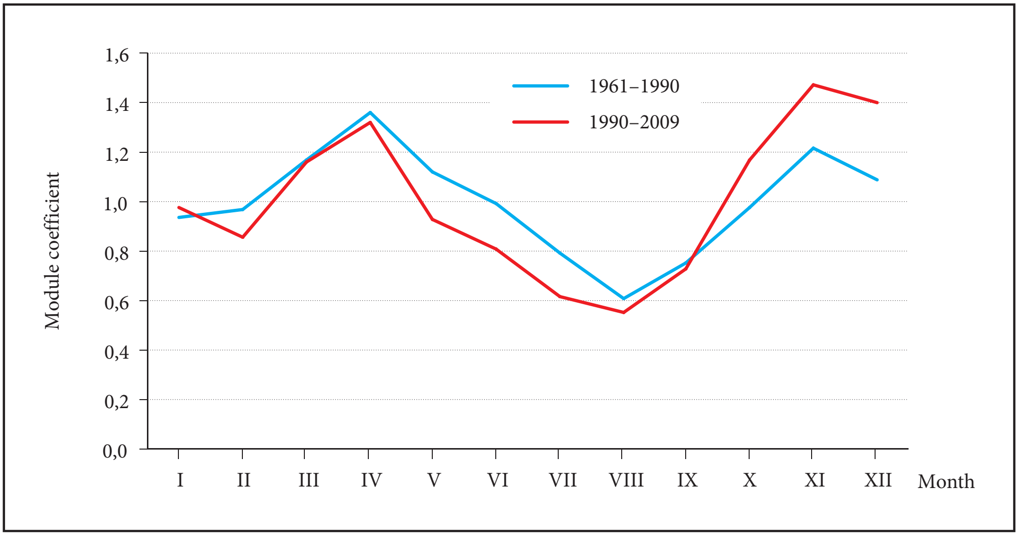

Figure 5: Module coefficient values of the Sava River at the Zagreb station; a Peripannonian pluvial-nival regime.

Comparing the Sava regime in the two periods, one can observe changes as a consequence of climate element changes, primarily in Slovenia (Brilly et al. 2007; Ulaga et al. 2008). The decreased discharge in late spring (May) and early summer (June) is evidently a consequence of a reduced amount of snow in the total amount of precipitation in the drainage area. The decreased discharge values in the summer months are a result of atmospheric pressure, rising evapotranspiration rates, and a decreasing amount of precipitation (Šegota and Filipčić 2007). Higher autumn discharges are a consequence of the prevailing rain input in comparison to snow. The same trend was detected for the Sava River in Slovenia (Frantar 2003). On the whole, the mean discharge value has dropped by about 11%, from 310.12 m^3/s to 274.25 m^3/s. This drop in discharge is marked in all months except October and December. This trend in falling mean annual discharge values has been detected since the mid-1920s (Šegota and Filipčić 2007; Bonacci and Oskoruš 2011). However, this trend (of falling mean discharges) has accelerated in the last twenty-year period, and it needs to be taken into consideration in further water management and planning as well as the construction of five new hydropower plants on the lower course of the Sava River in Slovenia.

3.4 Pannonian pluvial-nival regime

Rivers with a Panonnian pluvial-nival regime are the Bijela, Orljava, Toplica (Daruvarska), Glina, Sava (Županja Stepenica station), Voćinka, Vučica, Bid, Lonđa, and Sunja. These are mainly smaller streams in the Panonnian part of Croatia. This group includes the downstream regime of the Sava at the Županja station, which is somewhat different from the regime of the Sava in the upper and middle part of its course in Croatia. Unfortunately, we do not have data series long enough for a sufficient number of stations with this regime, and so it is impossible to draw general conclusions about the changes specific to this type of regime. Nevertheless, it is possible to perform an analysis of the Sava regime change at the Županja Stepenica station, for which there is a data series long enough (Figure 6).

Mean monthly discharge for the 1961–1990 period was 1,134.16 m^3/s, whereas the discharge for the 1990–2009 period was about 10% lower, at 1,026.28 m^3/s. Such a relatively large fall is the result of an absolute fall from January to September and a relative fall during the months before and after the spring maximum, which is in April. Except for similar changes in the upper stream part of the basin in Croatia and Slovenia, this is a consequence of the reduced amount of snowmelt in the input of main right-side tributaries (draining the Bosnian mountains), which affects the Sava regime downstream of Jasenovac

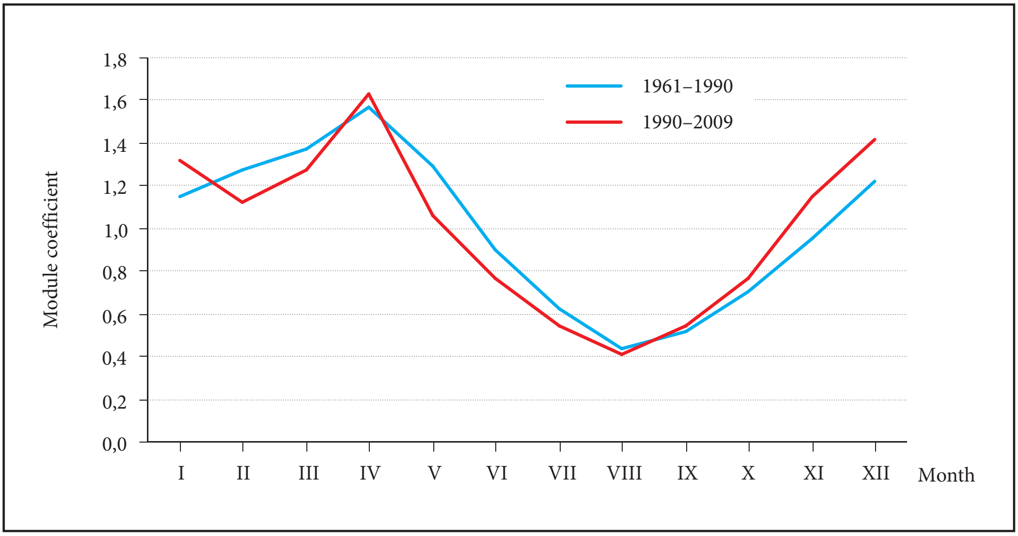

Figure 6: Module coefficient values of the Sava River at the Županja stepenica station; a Pannonian pluvial-nival regime.

(Hidrološka … 2012). Due to this station's large drainage area, which encompasses different climate areas and runoff conditions, the relationships in this case are among the most complex in Croatia.

3.5 Pannonian pluvial regime

The Česma, Ilova, and Kutina rivers have a Pannonian pluvial regime. The basic changes in the case of this regime type are shown in the example of the Česma River at the Narta station (Figure 7). The mean

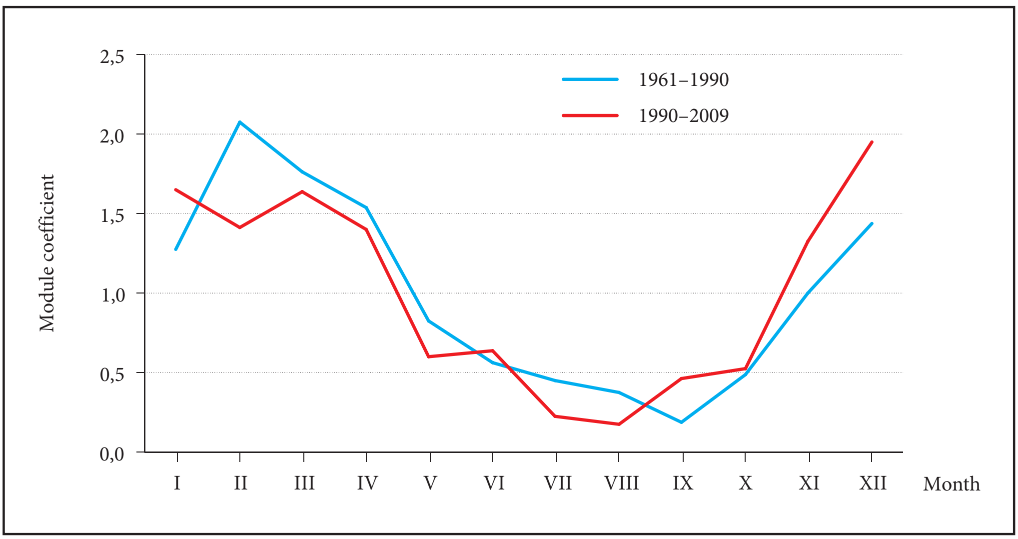

Figure 7: Module coefficient values of the Česma River at the Narta station; a Pannonian pluvial regime

monthly discharge between the two periods observed decreased by about 7%, from 5.2 m^3/s to 4.84 m^3/s. The highest increase in module coefficients is typical for autumn and partly for the winter months; for example, in December the increase moved from 1.44 to 1.95. On the other hand, the biggest decrease is significant for February, March, and the summer months.

The relative decrease in July and August is particularly significant. Due to such redistribution of discharge in the course of the year, the primary maximum shifted from February to December, and the minimum moved from September to August or even July. The changes in the colder part of the year are probably a consequence of the increase in the amount of autumn precipitation, and the decreases in July and August could also be explained by continuation of the already determined increase in temperature and rise in evapotranspiration during the warmest part of the year (Zaninović and Gajić-Čapka 1999). These changes, together with the decrease in the highest module coefficient values and an even greater relative fall in the lowest values, suggest that in the following period in this area water shortages and drought in the summer months can be expected more frequently.

3.6 Mediterranean pluvial-nival regime

This regime type is characteristic of 22% of the stations analyzed, which are mainly located on karst streams belonging to the Adriatic Basin. These are the Cetina, Vrljika, Jadro, Ombla, Krka (the Skradinski Buk Gornji station), Zrmanja, Lika, Novčica, Istrian Mirna, Pazinčica, and Rječina Rivers. This type includes two rivers of the Black Sea Basin: the (Donja) Dobra and Korana rivers. The characteristics of this regime and its changes in relation to the standard period are analyzed based on the example of the Krka River at the Skradinski Buk Gornji station (Figure 8). First, it is necessary to point out that in the case of the Krka River the mean monthly discharge values also decreased, by about 12%, from 54.16 m^3/s to 47.4 m^3/s.

In addition, one can observe a transition from a simple regime with one maximum and one minimum towards a regime with a marked second maximum in April and minimum in February and March. The increase in module coefficients has been recorded from November to January, but was especially marked in December and April. On the other hand, a significant decrease is characteristic for February and March. Apart from that, there are smaller decreases in the summer months, which can be alarming considering that a major part of the rivers with this regime have a crucial role in water supply.

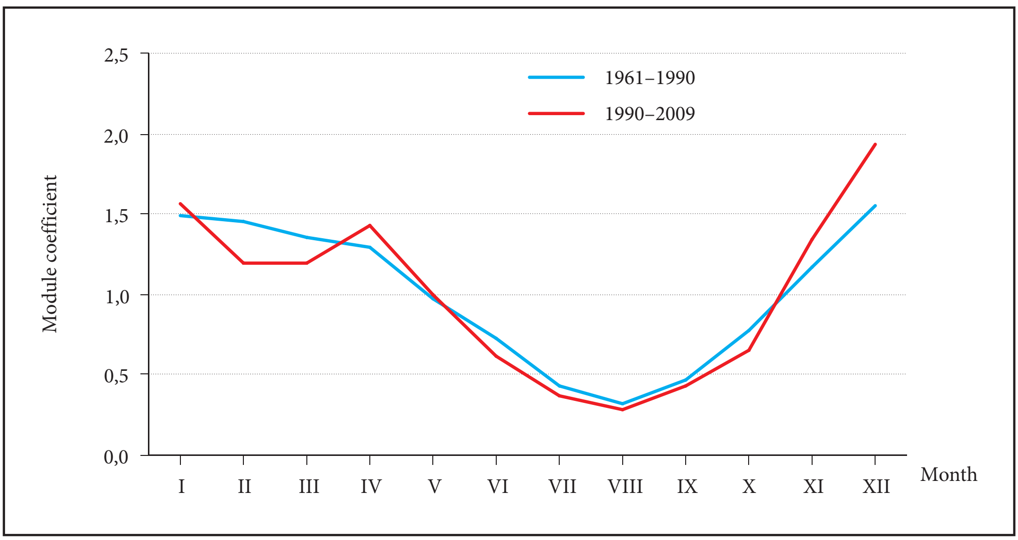

Figure 8: Module coefficient values of the Krka River at the Skradinski Buk Gornji station; a Mediterranean pluvial-nival regime.

3.7 Mediterranean pluvial regime

According to the typology made by Čanjevac (2013), only three stations on two streams belong to this regime: the Čikola River (stations: Ružić 1 and Ključice) and the Jadova River in Lika. These streams are threatened by a significant decrease in mean monthly values of discharge over the last twenty years. For the Čikola River (the Ružić 1 station) it amounts to nearly 25%, from 5.04 to 3.85 m^3/s. These data are alarming because the Čikola is an important stream in the water supply system of the town of Drniš and the surrounding area. Such a high decrease in discharge corresponds to a general trend in the Mediterranean (Ludwig et al. 2009). The changes in regime refer to a decrease in the coefficients in the autumn months, shorter and more intense duration of the winter maximum, and a more variable spring discharge (Figure 9).

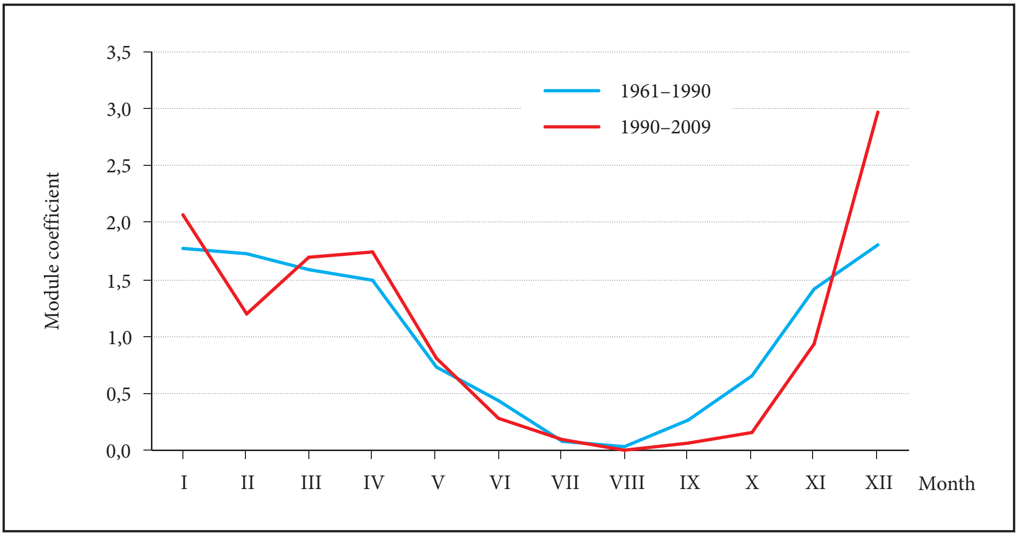

Figure 9: Module coefficient values of the Čikola River at the Ružić 1 station; a Mediterranean pluvial regime.

4 Discussion

The analysis of changes in discharge regimes in the last twenty-year period reflects a complex picture, and in most cases this could be related to changes in climate elements. Over the last century, lowland (i.e., central and eastern) Croatia has generally shown a mild increase in mean annual air temperature, a decrease in the precipitation quantity and soil humidity, and an increase in potential evapotranspiration with a statistically significant trend since 1987 (Zaninović and Gajić-Čapka 1999). Furthermore, the precipitation variability in continental Croatia increases towards the east (Maradin 2011; Maradin and Filipčić 2012). Larger rivers in the continental part (the Sava, Drava, and Mura rivers) exhibited a change in discharge regime primarily as a consequence of changing conditions in the upstream countries; that is, Slovenia (Frantar 2003, 2005, 2007) and Austria (Fürst et al. 2008, 2010). In these cases, the basin size and strong human interventions make the causal relationship of climatic elements change and runoff less clear, although observed signals are the same. A great number of hydroelectric power plants have been constructed on all three rivers, especially on the Drava (23) and Mura (26). Given that their construction has further stabilized the already steady discharge regime, the consequences of climatic changes are impossible to detect. There is evidence of increased discharge; namely, values of module coefficients in the spring, especially for rivers fed by snowmelt. Together with the evidence of an increase in mean annual temperature, this suggests that due to warmer winters with less snow (for the change in snow cover, see Gajić-Čapka 2011) there is a change in the ratio of solid to liquid precipitation in favor of rainfall. This reduces the retardation effect of the colder months on water resources, the amount of runoff is distributed, and the spring maxima shift toward the winter months. Such trends and processes are consistent with those in the Alps (Frantar 2005; Birsan et al. 2005; Fürst et al. 2010). A decrease in the values of module coefficients in the summer months is noticed at all stations analyzed. The most pronounced decrease is for rivers with simple Pannonian and Mediterranean pluvial regimes. This is probably the result of their higher sensitivity to precipitation variability and climate oscillations in general. In addition, for the entire Mediterranean there is a significant trend of a decrease in mean discharges over the last fifty years (Ludwig et al. 2009). The nearly uniform trend of the module coefficient increase in the autumn months is a consequence of the aforementioned trend of a change in the ratio of solid to liquid precipitation in favor of rainfall. Winter months showed an increase in module coefficients in most cases, but also the occurrence of a secondary minimum, usually in February.

5 Conclusion

Our comprehensive study of changes in discharge regimes of rivers in Croatia comparing the 1961–1990 and 1990–2009 periods yields the following general conclusions presented at the seasonal level:

- A decrease in module coefficients in the spring months, especially for rivers fed by snowmelt.
- A decrease in module coefficients in the summer months at all stations analyzed. The most pronounced decrease is for rivers with a simple Pannonian pluvial regime and especially a Mediterranean pluvial regime.
- A nearly uniform increase in module coefficients in the autumn months.
- An increase in module coefficients in winter months in most cases, but also the occurrence of a secondary minimum, usually in February.

The changes are in general the result of changes in climate elements (mainly a temperature rise) between the two periods. The most pronounced are changes in snow occurrence and accumulation processes. Given that many rivers in Croatia have a transboundary character, the conclusion above is supported by the results of studies in upstream countries. Projections of a further decrease in snow cover duration and thickness in the Alpine area in the twenty-first century have to be taken into consideration for further planning (Steiger 2010). The intensity of change for relatively lower elevations (from 600 to 1,300 m) is particularly stressed.

5 References

Belz, J. U., Goda, L., Buzás, Z., Domokos, M., Engel, H., Weber, J. 2004: Flow regime of river Danube and its catchment – an update of Chapter II of the Danube Monograph. Koblenz.

Birsan, M.-V., Molnar, P., Burlando, P., Pfaundler, M. 2005: Streamflow trends in Switzerland. Journal of hydrology 314, 1–4. DOI: http://dx.doi.org/10.1016/j.jhydrol.2005.06.008

Bonacci, O., Ljubenkov, I. 2008: Changes in flow conveyance and implication for flood protection, Sava River, Zagreb. Hydrological processes 22-8. DOI: http://dx.doi.org/10.1002/hyp.6688

Bonacci, O., Oskoruš, D. 2011: Hidrološka analiza sigurnosti Zagreba od poplave vodama rijeke Save u novim uvjetima. Hrvatske vode 19-75.

Bormann, H. 2010: Runoff regime changes in German rivers due to climate change. Erdkunde 64-3. DOI: http://dx.doi.org/10.3112/erdkunde.2010.03.04

Brilly, M., Horvat A., Matthews, D. Šraj, M. 2007: Climate change impact on mean annual river flows. Proceedings of the Third international conference on climate and water. Helsinki.

Croatian Bureau of Statistics, Statistical yearbook 2014. Internet http://www.dzs.hr/default_e.htm (11. 6. 2015).

Čanjevac, I. 2013: Typology of discharge regimes of rivers in Croatia. Hrvatski geografski glasnik 75-1.

Dukić, D. 1984: Hidrologija kopna. Beograd.

Frantar, P. 2003: Pretočni režimi na reki Savi in njihove spremembe med obdobjem 1961–1990 in 1991–2000. 14. Mišičev vodarski dan. Ljubljana.

Frantar, P. 2005: Pretočni režimi slovenskih rek in njihova spremenljivost. Ujma 19.

Frantar, P. 2007: Geographical overview of water balance of Slovenia 1971–2000 by main river basins. Acta geographica Slovenica 47-1. DOI: http://dx.doi.org/10.3986/AGS47102

Frantar, P., Hrvatin, M. 2005: Pretočni režimi v Sloveniji med letoma 1971 in 2000. Geografski vestnik 77-2.

Fürst, J., Kling, H., Nachtnebel, H. P., Hörhan, T. 2008: Trends in hydrologischen Variablen und in der Wasserbilanz Österreichs. Auswirkungen des Klimawandels auf die österreichische Wasserwirtschaft. Vienna.

Fürst, J., Kling, H., Nachtnebel, H. P., Hörhan, T. 2010: Beobachtete Veränderungen in der Wasserbilanz Österreichs. Auswirkungen des Klimawandels auf Hydrologie und Wasserwirtschaft in Österreich – Präsentation der aktuellen Studien. Vienna.

Gajić-Čapka, M. 2011: Snow climate baseline conditions and trends in Croatia relevant to winter tourism. Theoretical and applied climatology 105-1. DOI: http://dx.doi.org/10.1007/s00704-010-0385-5

Gajić-Čapka, M., Cesarec, K. 2010: Trend i varijabilnost klimatskih veličina u slivu rijeke Drave. Hrvatske vode 18-71.

Grimm, F. 1968: Das Abflussverhalten in Europa – Typen und reginale Gliederung. Leipzig.

Hidrološka studija površinskih voda Bosne i Hercegovina 2012. Sljiv reke Bosne. Sarajevo.

Hrvatin, M. 1998: Discharge regimes in Slovenia. Acta geographica 38.

Ilešič, S. 1948: Rečni režimi v Jugoslaviji. Geografski vestnik 19.

Knežević, R. 2001: Osnovne značajke režima poriječja Rječine. Acta Geographica Croatica 34.

Knežević, R. 2004: Uvjeti otjecanja i režim tekućica u porječju Mirne. Hrvatski geografski glasnik 65-2.

Kovács, P. 2010: Characterization of the Runoff Regime and Its Stability in the Danube Catchment. Hydrological Processes of the Danube River Basin. Amsterdam.

Ludwig, W., Dumont, E., Meybeck, M., Heussner, S. 2009: River discharges of water and nutrients to the Mediterranean and Black Sea: Major drivers for ecosystem changes during past and future decades. Progress in oceanography 80, 3-4. DOI: http://dx.doi.org/10.1016/j.pocean.2009.02.001

Maradin, M. 2011: Geografski aspekt razlika u varijabilnosti padalina kontinentskog i maritimnog pluviometrijskog režima u Republici Hrvatskoj. Doctoral thessis. University of Zagreb, Faculty of Science. Zagreb.

Maradin, M., Filipčić, A. 2012: Prostorne razlike u varijabilnosti padalina Središnje Hrvatske. Hrvatski geografski glasnik 74-1.

Meteorological and Hydrological Service of Croatia, Database of monthly discharge data, 2014. Zagreb.

Orešić, D. 1995: Osnovne značajke režima tekućica poriječja Krapine. Hrvatski geografski glasnik 57-1.

Pandžić, K., Trninić, D., Likso, T., Bošnjak, T. 2009: Long-term variations in water balance components for Croatia. Theoretical and Applied Climatology 95. DOI: http://dx.doi.org/10.1007/s00704-007-0366-5

Pardé, M. 1933: Fleuves et rivieres. Paris.

Pejnović, D. 1991: Režim tekućica kao indikator općih hidrogeografskih obilježja Like. Hrvatski geografski glasnik 53-1.

Riđanović, J. 1993: Hidrogeografija. Zagreb.

Shaw, E. M., Keith, J. B., Chappel, N. A., Lamb, R. 2010: Hydrology in Practice. New York.

Steiger, R. 2010: The impact of climate change on ski season length and snowmaking requirements in Tyrol, Austria. Climate research 43-3. http://dx.doi.org/10.1108/16605371111175285

Šegota, T., Filipčić, A. 2007: Contemporary climate changes and decrease of Sava river flow through Zagreb. Geoadria 12-1.

Ulaga, F. 2002: Trendi spreminjanja pretokov slovenskih rek. Dela 18.

Ulaga, F., Kobold, M., Frantar, P. 2008: Trends of river discharges in Slovenia. Earth and environmental science 4. DOI: http://dx.doi.org/10.1088/1755-1307/4/1/012030

Zaninović, K., Gajić-Čapka, M. 1999: Changes in components of the water balance in the Croatian lowlands. Theoretical and applied climatology 65, 1–2. DOI: http://dx.doi.org/10.1007/s007040050008